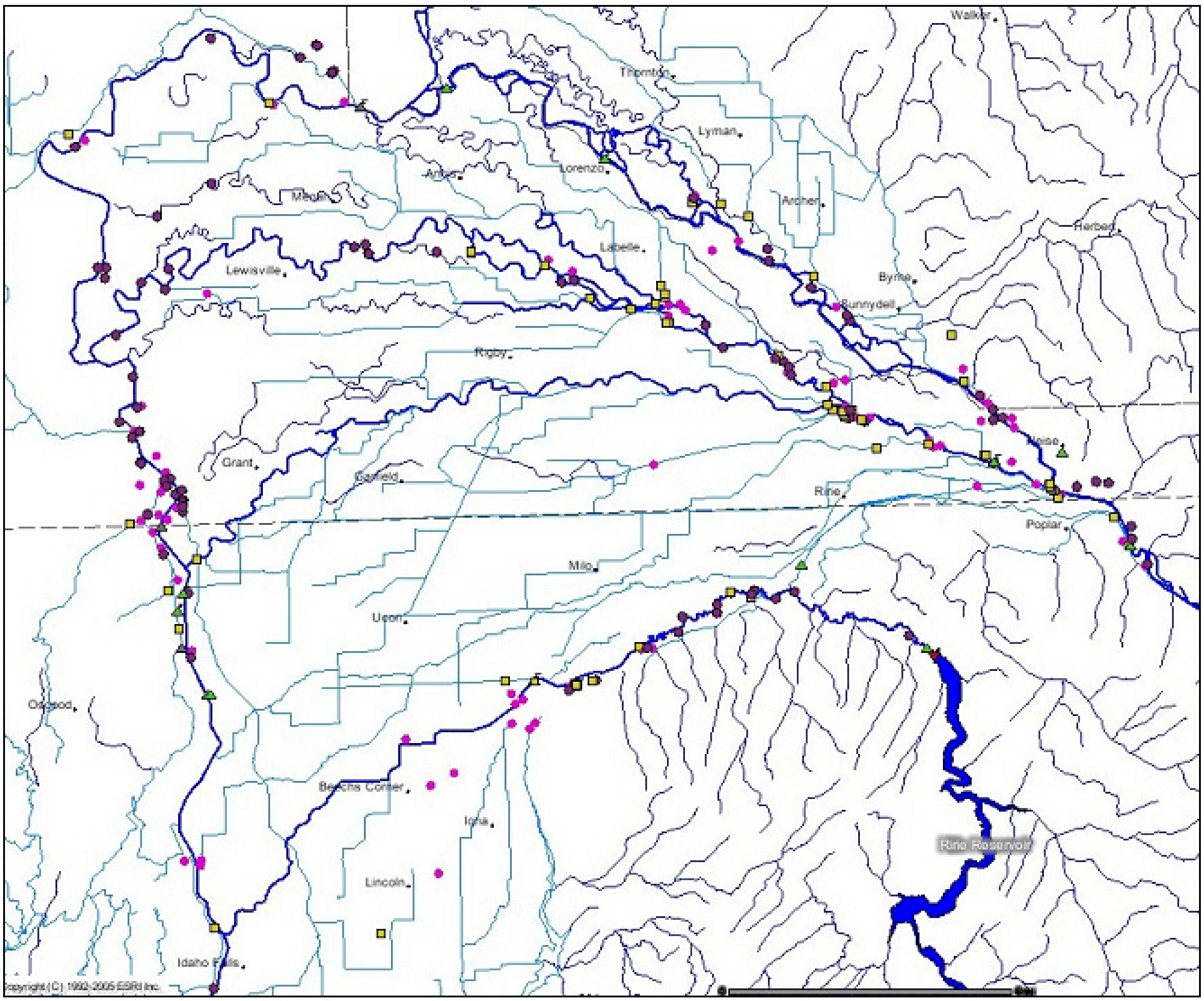
New Tools
for
Water Rights Accounting

Project Description and Status



This document is in constant revision.
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Table of Contents

1.0 Introduction 2
2.0 Project Goal 3
3.0 Project Objectives 3
4.0 Introduction 3
4.1 Water Rights Accounting 3
4.2 The Water Rights Accounting Project 3
4.2.1 History of Water Rights Accounting 4
4.2.2. Project Motivation 4
4.2.3. Project Description 4
4.2.4 Bureau of Reclamation Contract 5
4.3 Planned Evolution the Models 5
5.0 Project Schedule 7
6.0 Detailed Description of initiatives 8
6.1 Initiative 1: Back-up of Accounting Models to PC 8
6.1.1. Initiative Goal 8
6.1.2. Initiative Objective 8
6.1.3 Context 8
6.1.4 Tasks 9
6.1.5 Status 9
6.2. Initiative 2: Public Internet Access to the Accounting Model(s) 10
6.2.1 Initiative Goal 10
6.2.2 Initiative Objectives 10
6.2.3 Proposed application functions 10
6.2.4 Tasks 11
6.2.5 Status 12
6.3 Initiative 3: Implement GIS as a front and back end for the model(s). 12
6.3.1 Initiative Goal 12
6.3.2 Initiative Objectives 12
6.3.3 Rationale 13
6.3.4 Context 13
6.3.5 Tasks 14
6.3.6 Status 14
6.4 Initiative 4: Review and Evaluate the Fortran Code 14
6.4.1 Introduction 14
6.4.2 Initiative Goal 15
6.4.3 Initiative Objectives 15
6.4.4 .NET Environment 15
6.4.5 Defined Upgrade Path 15
6.4.6 Tasks 15
6.4.7 Status 15
6.5 Initiative 5: Document Water Rights Accounting 15
6.5.1 Initiative Goal 15
6.5.2 Initiative Objectives 15
6.5.3 Tasks 16
6.5.3 Status 16
6.6 Initiative 6: Develop a Strategy to Keep the Model Current 16
6.6.1 Introduction 16
6.6.2 Initiative Goal 16
6.6.3 Initiative Objective 16
6.6.4 Tasks 17
6.6.5 Status 17
7.0 Glossary 18
8.0 References 20
9.0 Appendix 1 Generalized data flow 21
10.0 Appendix 2 Project Personnel 22

1.0 Introduction

"Scientists have a terrible tendency to present their work as a logical package, as if they thought everything out in careful and rigorous planning beforehand and then merely proceeded according to their good designs. It never works out that way, if only because anyone who can think and see makes unanticipated discoveries and must fundamentally alter any preconceived strategy. Also, people get into problems for the damnedest of peculiar and accidental reasons. Projects grow like organisms, with serendipity and supple adjustment, not like the foreordained steps of a high school proof in plane geometry."

- Stephen J. Gould

The project to create new tools for water rights accounting, as reflected in this planning document, is consistent with Gould's description: both the project and this document are modified regularly as the project proceeds. The modifications come when tasks are completed, added, or modified to adjust for lessons learned as the project progresses.

At the beginning of the project, the project personnel had a goal clearly in mind for what water-rights accounting should be in the not-too-distant-future. This document began as a statement describing that goal. The project personnel met regularly to generate specific ideas about how to move the project in the direction needed to achieve that goal. Ideas were incorporated into this document, and transformed into the separate initiatives and tasks. All the project participants meet weekly to report progress, discuss roadblocks, review needed outcomes, and brainstorm solutions. The results of those meetings are incorporated into this document.

Creating new tools for water-rights accounting requires melding several separate disciplines into a seamless application. It is a complex process. The new tools being developed are centered around a Geographic Information System. Water rights and the various components of water-rights accounting are all spatial data. GIS is a broad discipline of philosophies, knowledge, algorithms, software packages, and specific software tools, all of which are specifically designed for processing spatial data.

If this project does proceed as Gould describes, like an organism, then it will continue to grow and change beyond the bounds described here. If the process is done correctly, water rights accounting will continue to change as new technologies are adopted, will become more sophisticated as new capabilities are added, and will be more tightly integrated into other, related functions within the department.

2.0 Project Goal

Make water rights accounting an open and transparent process that can be examined by the public via the Internet.

3.0 Project Objectives

1. Redesign and simplify the current water rights accounting models into a GIS environment with integrated tools for data visualization and plotting.

2. Make model input data and results accessible over the Internet.

3. Develop and integrate QA/QC procedures.

4.0 Introduction

4.1 Water Rights Accounting

The IDWR Hydrology Section runs five accounting models for surface-water rights in five Idaho river basins. The five basins are 1) the Payette, 2) the Boise, 3) the Big Lost, 4) the upper Snake, and 5) the Bear. These basins contain most of the surface-water irrigated land in Idaho. The first basin model was written in 1978, with other models following at later dates. All the models are written in Fortran, and run in substantially the same way they did when they were first coded.

The purpose of water rights accounting is to compute the amount of both natural flow and storage water that is allocated on a daily basis for selected points of diversion (PODs) in each basin. The selected points of diversion supply water to groups of water rights. The daily computations are used by water masters to actually distribute the water, also on a daily basis. At the end of the irrigation year, the models are used to determine the amount of storage to be carried over for each POD.

4.2 The Water Rights Accounting Project

This project is designed to modernize the accounting process by incorporating up-to-date information-technology tools that are not now part of the process. These tools include a relational database management system (RDBMS), a geographic Information system (GIS), and the Internet.

This work described here is both focused and open-ended. It is focused because it includes specific tasks needed to fulfill a contract with the U.S. Bureau of Reclamation (USBR). It is open-ended because the model, as implemented in GIS, will be evolutionary rather than static, and additional capabilities can be added as they are needed.

4.2.1 History of Water Rights Accounting

IDWR initiated a computer-based method of water rights accounting in response to the drought of 1977. The original accounting implementation is described in Sutter, et al. (1982). The stated purpose of using a computer-based method was “to better manage the Upper Snake water resources.”

At the beginning of this project, IDWR had 5 separate water rights accounting ‘models’, one each for five river basins: the Payette, the Boise, the Big Lost, the Upper Snake, and the Bear. The five ‘models’ are actually five Fortran programs.

4.2.2. Project Motivation

The motive in modernizing the accounting process is address 5 present deficiencies: 1) The model now runs on obsolete hardware. 2) Personnel retirements have left IDWR without any of the personnel who developed the accounting models. 3) Conjunctive administration has led to increased scrutiny of the amount of surface water and to whom the water is delivered. 4) Litigation has resulted in requests for model software and data. 5) The functionality of Information Technology (IT) tools has increased steadily since 1977, but essentially none of that functionality has been incorporated in to the modeling process.

4.2.3. Project Description

The project has 5 initiatives, or phases. The initiatives are being done largely in parallel rather than in series. The following is a brief description of the initiatives. A detailed description follows in Section 5.0.

Initiative 1: Duplicate the Alpha accounting modeling environment on the PC. This duplication will serve as a back-up to the models that now run on a DEC Alpha. This porting is needed because DEC no longer exists, and the Alpha hardware and operating system (VMS) are obsolete. The goal of this initiative is to duplicate the present output from the Alpha implementation of the models. No changes will be made to the models. RDBMS will replace the DEC Command Language as the means of processing the input data. Initiatives 3 and 4 will incorporate the RDBMS functions written for Initiative 1.

Initiative 2: Make the models’ input data and results available to the public through the Internet. Initiative 2 fulfills “Task 2.04 Internet Access” of Purchase Order #03PG110240 from the U.S. Bureau of Reclamation. In that purchase order, the task description is as follows:

“The purpose of this task is to provide public access to the database and model results. Web applications will be written to display input data and results. Internet users will also be able to download input data and model results. It will also create the tools necessary to create custom reports for other needs.”

Initiative 3: Implement GIS as a front and back end for the model(s). Initiative 2 fulfills “Task 2.04 Internet Access” of Purchase Order #03PG110240 from the U.S. Bureau of Reclamation. In that purchase order, the task description is as follows:

"Depending on the needs defined by the end users, applications to link to other databases may be required. These applications include GIS Spatial Database Applications for accounting model input and output and applications for the IDWR Planning Model. One application would be to display the location of rivers and canals, points of diversion, measuring points, and water rights. This interface would make updating and understanding the accounting model input much easier and reduce the errors in setting up the accounting model."

Initiative 4: Review and Evaluate the Fortran Code. Fortran and relational databases have different capabilities. The Fortran code of the model will be reviewed to see if some of the functionality now hard-coded into Fortran can better be implemented in RDBMS.

Initiative 5: Document Water Rights Accounting. The accounting program assigns numerical values for such items as reservoir storage rights and combined diversion volumes. The reasons for assigning specific values are not presently documented. In order to assure that water rights accounting is an accurate process, those numerical values need to be documented.

Initiative 6: Develop a Strategy to Keep the Model Current. Information Technology, in the form of hardware, software, and connectivity, evolves rapidly. Water Rights Accounting, as a business process, needs to be reviewed regularly to evaluate how it can take advantage of advances in Information Technology.

4.2.4 Bureau of Reclamation Contract

The impetus for project was a contract with the USBR. The contract, designated as Purchase Order 03PG110240, was signed in September, 2003. The purpose of the contract was two-fold. The first purpose was to develop a publicly accessible database for stream flow, diversion data, and other data required for water administration. The second purpose was to improve and expand the IDWR water rights accounting model for three river basins, the Payette, the Boise, and the Upper Snake. Under the contract, IDWR committed to 1) design a relational database to support water rights accounting, 2) construct the database, 3) populate the database with historical data, 4) write data entry applications, 5) write database retrieval applications, 6) write data display applications, 7) implement the models in GIS, and 8) create a means for the public to access model input and results over the internet.

The USBR contract is the foundation of a much larger project. The project will continue well after the USBR contract is completed.

4.3 Planned Evolution the Models

Three diagrams serve to illustrate the planned evolution of the hydrologic accounting models. Figure 1 is a conceptual diagram of the water rights accounting models as they existed at the start of the project. Figure 2 is a conceptual diagram of the models after completion of Initiative 1. Appendix 1 contains a generalized diagram of the actual data flow. Figure 3 is a conceptual diagram of the final, consolidated models.

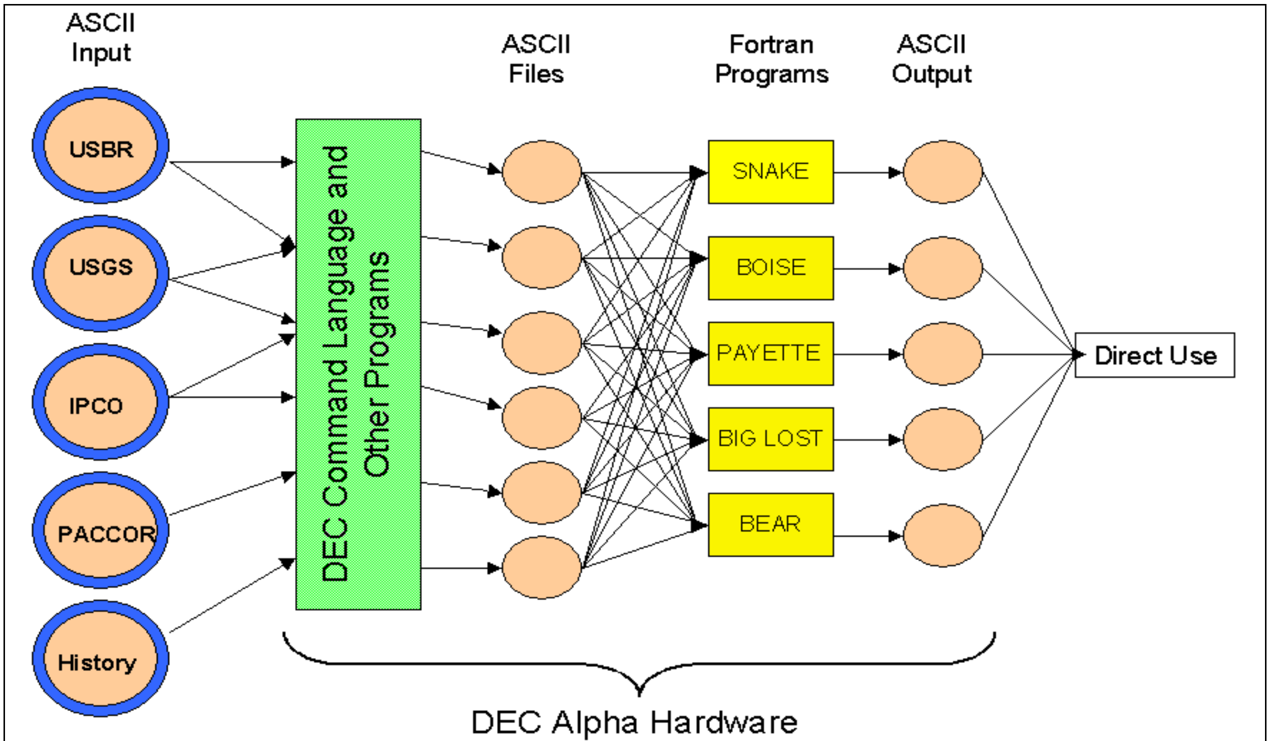


Figure 1. Conceptual diagram of the water rights accounting models as they existed at the start of the project

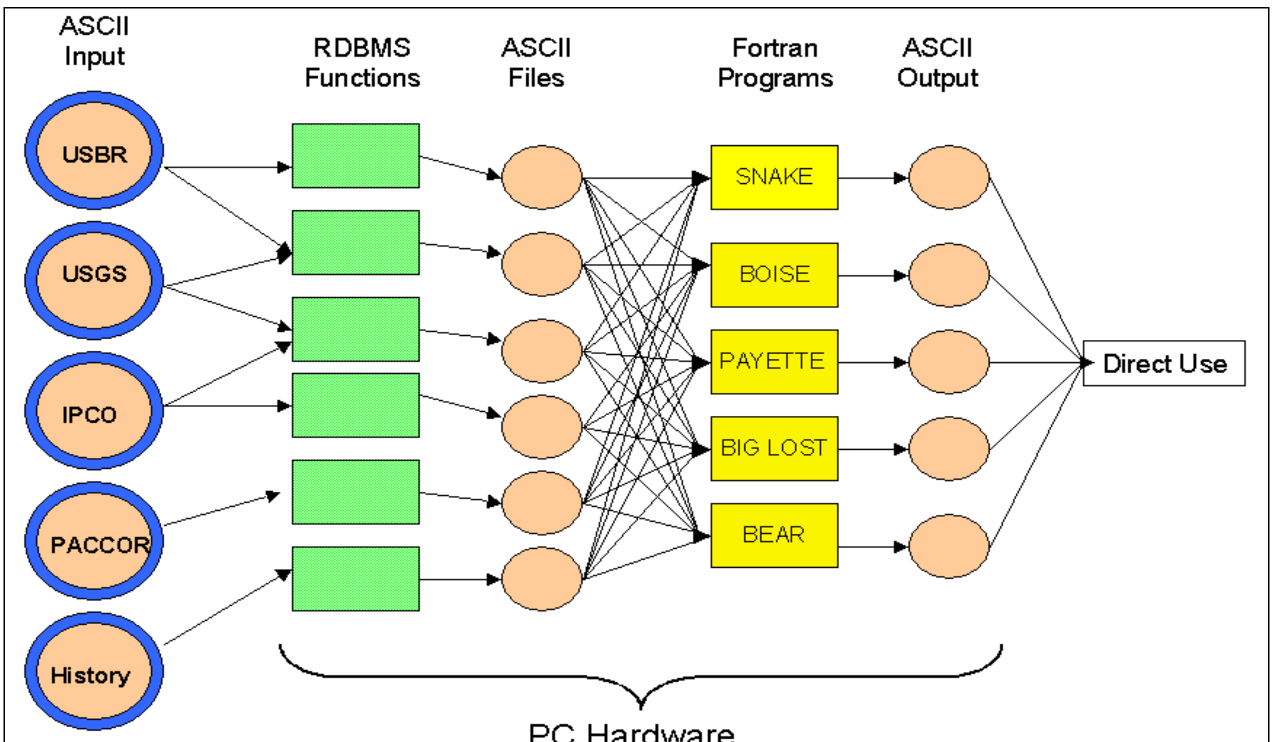


Figure 2. Conceptual diagram of the models after completion of Initiative 1.

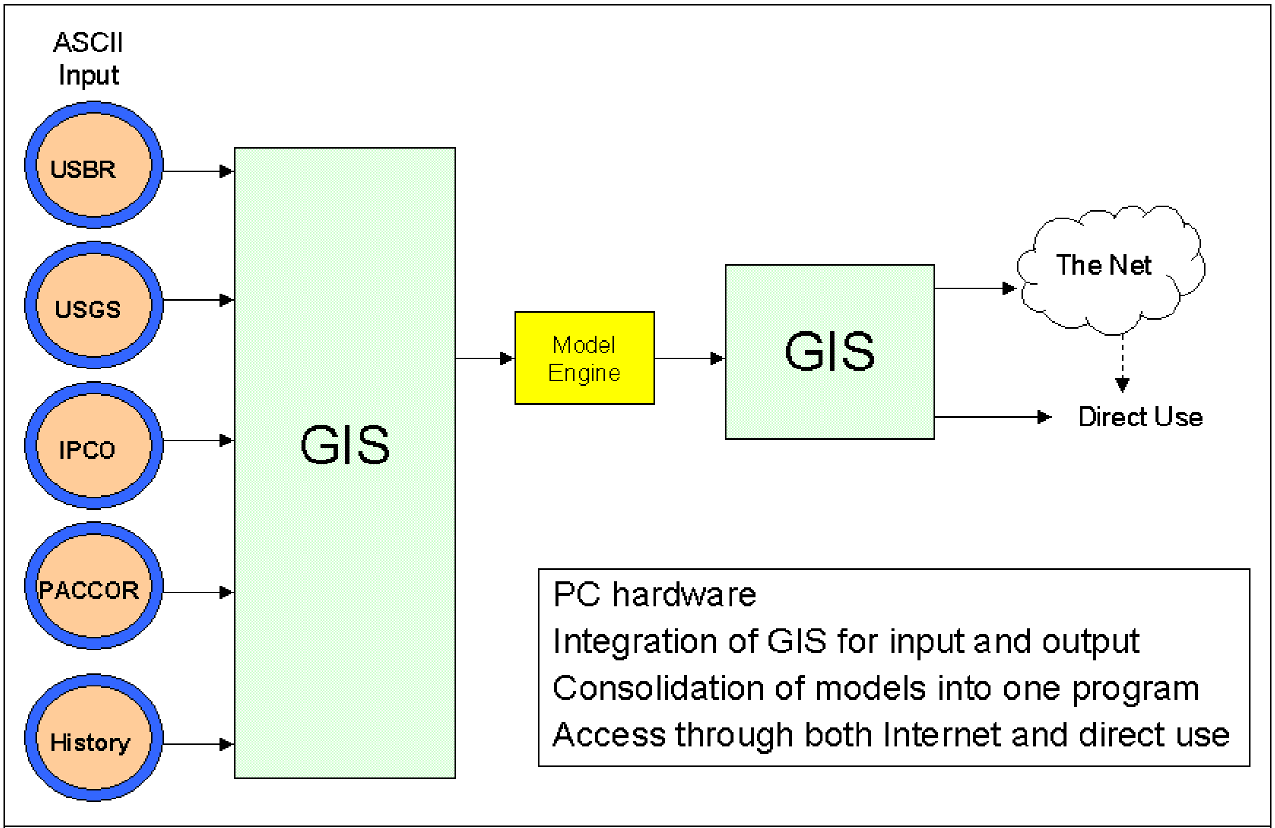


Figure 3. Conceptual diagram of the model after the completion of Initiative 4.

5.0 Project Schedule

The described functions of Initiatives 1 through 3 are expected to be completed in time to support the 2006 accounting season. Initiative 4 will be completed in time to support the 2007 accounting season. Initiative 5 will begin during the 2006 accounting season and be an on-going process designed to keep the accounting model(s) current with changes in Information Technology.

The initiatives have considerable overlap in time, and therefore are being done in parallel, not series. This is illustrated by Figure 4.

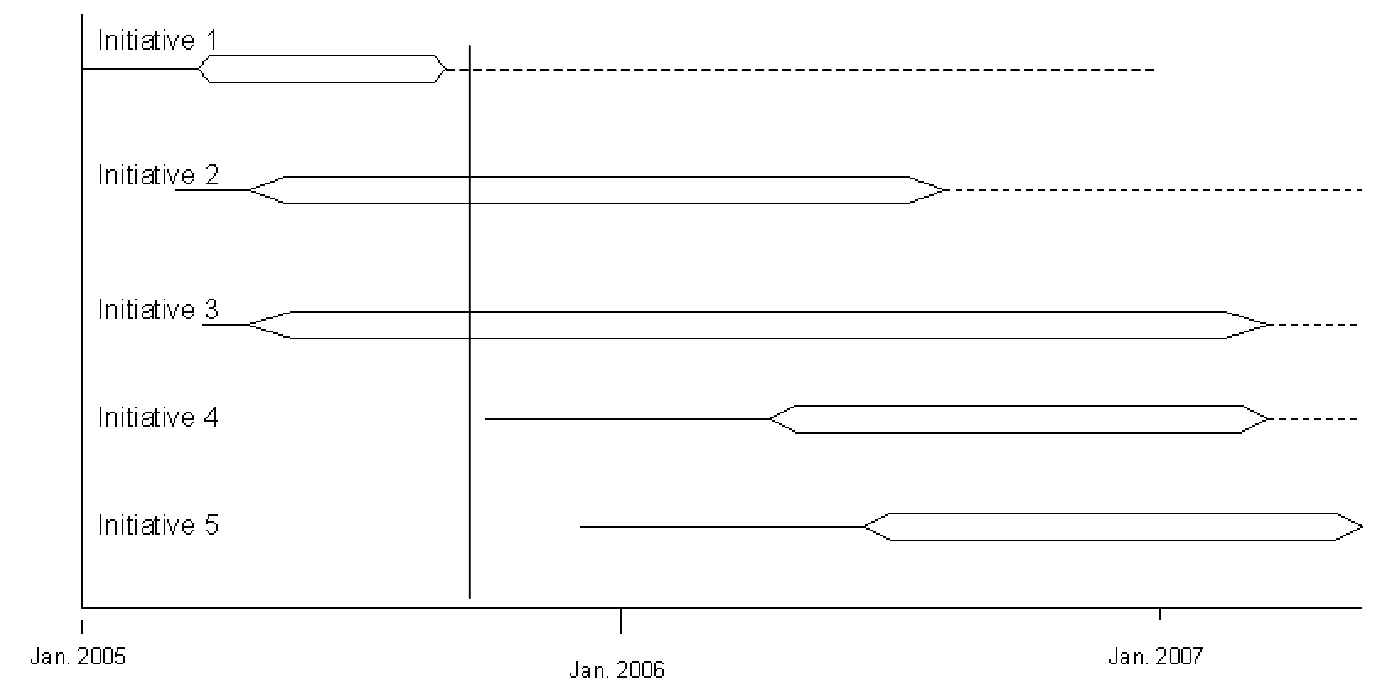


Figure 4. Relative timelines for the project initiatives. Thickness of the lines indicates relative level of effort.

6.0 Detailed Description of initiatives

6.1 Initiative 1: Back-up of Accounting Models to PC

6.1.1. Initiative Goal

Assure that the department can continue to run the accounting models in the event the Alpha fails. **GOAL ACHIEVED.**

6.1.2. Initiative Objective

Duplicate the functionality and results of the present accounting models on a Windows platform.

6.1.3 Context

Water rights accounting has been running on a DEC Alpha. The water rights accounting process needs to be migrated off the Alpha in order to integrate future increases in IT functionality because the Alpha is now a dead-end platform from the standpoint of both its hardware and its operating system.

DEC was bought out in 1998 by Compaq, and Compaq was bought out in 2002 by Hewlett Packard. The Alpha is a 64-bit RISC chip that was introduced by DEC in 1992. The present version of the Alpha, the EV7 is the last version that HP is going to produce.

The Alpha uses the DEC VMS operating system. Microsoft supported the Alpha through Windows NT 4.0, but not beyond. The present operating systems in use at IDWR, Windows 2000 and Windows XP do not support the Alpha.

IDWR PC hardware running Microsoft Windows operating systems. Water rights accounting needs to be migrated to the PC/Windows environment to be consistent with IDWR's computing environment.

6.1.4 Tasks

1. Establish nightly routine to copy of all WRA files from Alpha to WRA Server.

2. Install Source Safe on WRA user PCs and train on how to use it for ALL Fortran code, including control and indicator files.

3. Create SIMPLE database to store the main working data: HST, ALC, RTS, RRT, and others, and merge DPL and all TTLs to common table.

4. Problem exists that different data types are stored in the same "field" (line position) and interpreted based on the line type. Propose to make additional fields for really different data types, or separate tables for each point type.

5. Create an Access application to
   a) load working data from HST, ALC, and other ASCII files
   b) error check data (missing values, significant changes)
   c) graph data for current water year

6. Create an Access application to enter/edit working data from HST, ALC, and other ASCII files

7. Create an Access application to
   a) extract temporary data files to run WRA: HSF, HSD, HSR, HSE, ALD, ALR, ALM.
   b) merge run output data NAL or ALC back to working database tables

8. Modify existing WRA Fortran Accounting code to run under Intel Visual Fortran 8.0

9. Test run PC and Alpha versions in parallel and compare for identical output.

10. Create application to extract control and indicator parameters from database tables.

11. Create an Access application to
    a) graph data for selected water year
    b) graph data for average water year

12. Expand database to include configuration and control parameters.

13. Create application to generate ASCII configuration and control files

6.1.5 Status

All tasks are completed. The Fortran component of each of the five models has been compiled and run on the PC. The full PC version of the models for the Payette, the Boise, and the Snake all run on the PC. Conversion to the PC of those three models is covered by the contract between IDWR and the Bureau of Reclamation (BOR).

6.2. Initiative 2: Public Internet Access to the Accounting Model(s)

6.2.1 Initiative Goal

Increase the transparency of the accounting model(s)

6.2.2 Initiative Objectives

1. Allow the public to display input data and results over the Internet.
2. Allow the public to be able to download input data and model results.
3. Create the tools necessary to create custom reports for other needs.

6.2.3 Proposed application functions

1) Gage/Reach

Function	Status
a. Link to the USGS Real-time stream gage data for downstream node	report and download done
b. Link to the USGS Real-time stream gage data for upstream node	report and download done
c. Link to the USGS Gage height	report and download done
d. Link to the USGS most recent gage shift	report and download done
e. Previous historical data	report and download done
f. Reach gain (averaged and lagged) from daily accounting – (daily, cfs)	report only done
g. Reach gain (un-averaged and un-lagged computation) – (daily, cfs)	report only done
h. Last priority date filled in reach (daily, date)	report only done
i. Total diversion by pumps and canals in reach (daily, cfs)	report only done
j. Total exchange well pumping in reach (daily, cfs)	report only done
k. Total natural flow in reach (daily, cfs)	report only done
l. Remaining natural flow in reach (daily, cfs)	report only done

2) Reservoirs

Function	Status
a. Contents (acre-feet)	done for history file, but not current year
b. Elevation and / or gage height (daily, ft)	done for history file, but not current year
c. Evaporation (daily, cfs)	done for history file, but not current year
d. Precipitation (daily, inches)	done for history file, but not current year
e. Change in storage (daily, acre-feet and cfs)	done for history file, but not current year

3) Diversions

Function	Status
a. Total daily (cfs)	done for history file, but not current year
b. Natural flow used (daily, cfs)	done for history file, but not current year

c. Storage flow used (daily, cfs)	done for history file, but not current year
d. List of water rights for this diversion	done for history file, but not current year
e. List of water rights with volume restrictions	done for history file, but not current year
f. Gage height	done for history file, but not current year
g. Measured shift (daily, ft)	done for history file, but not current year
h. Interpolated shift (daily, ft)	done for history file, but not current year
i. Rating equation	done for history file, but not current year
j. Storage used (total acre-feet to date)	done for history file, but not current year
k. Storage remaining (total acre-feet to date)	done for history file, but not current year
l. Previous historical data	done for history file, but not current year

4) Exchange wells

Function	Status
a. Discharge (daily cfs)	done for history file, but not current year
b. Previous historical data	done for history file, but not current year

5) Pumps

Function	Status
a. Discharge (daily cfs)	done for history file, but not current year
b. Natural flow used (daily cfs)	done for history file, but not current year
c. Storage flow used (daily, cfs)	done for history file, but not current year
d. List of water rights for this diversion	done for history file, but not current year
e. List of water rights with volume restrictions	done for history file, but not current year
f. Previous historical data	done for history file, but not current year

6.2.4 Tasks

1. Identify and assemble the data sets. The data sets are tabular input data and model results, and map features such as river reaches, points of diversion, stream gages, and other hydrologic features. These data are needed for the ArcIMS application. Map features will go on the ArcIMS server, and the tabular data will go on the GIS server. ArcIMS will use only online data from A19. ArcIMS will not use a separate set of edited, clipped data-sets. ArcIMS will pull the data out of SDE, using the basin boundary to define the data extent (meeting of 8/4/05).

2. Coordinate with Hydrology Section personnel to ensure that all the necessary map features, are included and correctly attributed.

3. Design the application interface.

4. Link the map features with the appropriate input data and results.

5. Develop interface to graphing software.

6. Integrate pdf printing to enable public download of maps created in ArcIMS.

7. Assess the need for further application functionality and for any necessary modifications.

6.2.5 Status

The Initiative objectives have been achieved, although not for all of the proposed application functions.

Task 1: Identify and assemble the data sets.
Completed. The data sets have been identified and compiled. In addition to the data sets listed in Section 5.3.4, other data sets will be needed. Those additional data sets are aerial photography, state and county boundaries, USGS gages and diversions, and cities. The full set of data has been assembled for the all five basins, and set-up in ArcIMS for the Upper Snake, the Boise, and the Payette. The Upper Snake Basin is being used as the development vehicle for the Web mapping application. Color aerial photography with 1-meter pixels has been added.

Task 2: Coordinate with Hydrology Section personnel
Linda has been and is still actively working with both Hydrology Section and WD01 personnel.

Task 3: Design the application interface
Completed.

Task 4: Link the map features with the appropriate input data and results.
Completed for the Snake the Payette, and the Boise.

Task 5: Develop interface to graphing software.
Completed.

Task 6: Integrate pdf printing to enable public download of maps
Completed.

Task 7: Assess the need for further application functionality
On-going.

6.3 Initiative 3: Implement GIS as a front and back end for the model(s).

6.3.1 Initiative Goal

Make water rights accounting a spatially-enabled application.

6.3.2 Initiative Objectives

1) Set up a GIS front-end and back-end to the model engine. The GIS component will be separate from the modeling component as diagrammed in Figure 5. GIS will function as a front end and a back end to the accounting model.

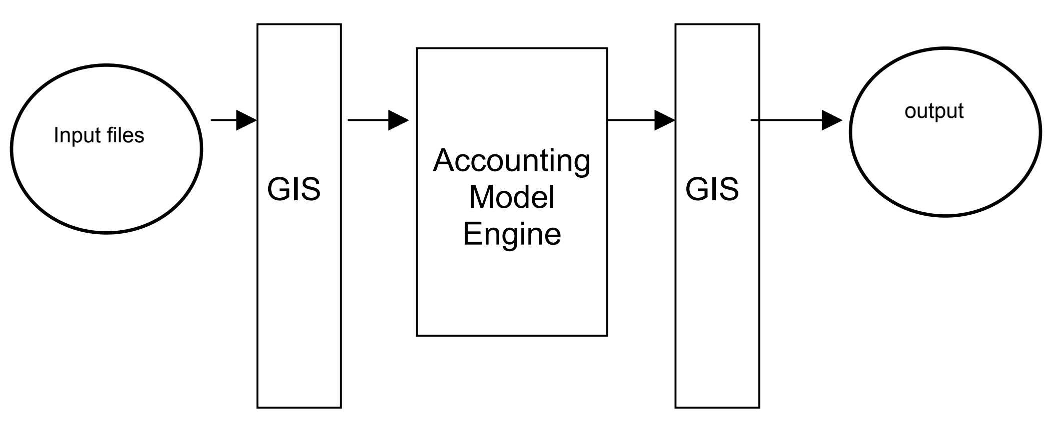


Figure 5. The general relationship between GIS and the model engine

2) Integrate accounting features into a geographic network having full topology.

6.3.3 Rationale

All input and output data for the model are spatial data. The input and output data now are handled in flat, tabular files that do not allow any visualization. By integrating GIS into the model, the input data can

a. be better controlled for quality
b. visualized in their spatial context
c. constrained by data-base rules

6.3.4 Context

a. Relational database files will be the actual front and back ends to the model engines.

b. The GIS implementation will be designed as a separate component from the accounting models such that modifications to the GIS component will not affect the running of the model engine, and modifications to the model engine will not affect the function of the GIS component.

c. The accounting models will not be modified by the integration of GIS.

d. The integration of GIS will require geometric network tools. Some of the tools will be taken from ArcHydro, and some of the tools will be custom-built.

e. The geometric network tools, as a suite, will be custom-designed specifically to support the IDWR accounting models.

f. The National Hydrography Data Set (NHD)will be used as the geometric network (meeting of 4/21/05). However, the NHD will not be used in its entirety because of the complexity of the database. The NHD will be streamlined to include only the com id and the reach ID (meeting of 8/4/05).

g. The following data sets are needed for a basic implementation of GIS (this list may not be comprehensive) (meeting of 4/21/05):

1) Reservoirs
2) Water Rights
3) Stream Gages
4) Points of Return
5) NHD Hydrography
6) Points of Diversion
7) Accounting Reaches
8) AgriMet station Locations
9) Exchange Wells
10) Other Irrigation Wells
11) Recharge Wells

6.3.5 Tasks

1. Assemble and prepare the NHD.

2. Assemble and prepare hydrologic data

6.3.6 Status

1. The NHD is assembled. The Idaho Hydrology Working Group still has works to do to make the NHD complete. IDWR has a contract with USGS to, among other things, add canal names and flow direction.

2. Diversion and return flow have been assembled. The data are going through QA/QC. Data have been integrated into ArcIMS applications for the Payette, the Boise, and the Upper Snake.

6.4 Initiative 4: Review and Evaluate the Fortran Code

6.4.1 Introduction

The Water Rights Accounting Model was originally written in the mid 1970s using Fortran, which was a commonly-available programming language. Fortran was designed for scientific and engineering applications, which dominated computer use at the time the accounting model was written.

One of the advantages of Fortran is its wealth of intrinsic mathematical functions. These functions are not used in the accounting models. The accounting process uses 3 arithmetic functions, addition, subtraction, and occasionally multiplication. The accounting model does require the mathematical functions of Fortran, but Fortran nevertheless can reasonably be used.

As computer applications have evolved over the last 30 years, programming environments have evolved as well. These new environments have spawned new languages that can be used profitably in the accounting model.

IDWR has a standard programming environment, Microsoft .NET. The engine of Water Rights Accounting will be implemented in .NET. The advantage of using .NET is 1) it integrates programming languages, and 2) it will have a defined upgrade path.

6.4.2 Initiative Goal

Modernize the model engine.

6.4.3 Initiative Objectives

1. Increase and assure accuracy.
2. Keep model development in a current environment.
3. Keep the model programming environment matched to a large pool of available, skilled programmers.

6.4.4 .NET Environment

Integrating programming languages is an advantage because different languages have different strengths. The FORTRAN of the model engine is not appropriate for writing GUIs.

6.4.5 Defined Upgrade Path

Upgrade path

6.4.6 Tasks

1. review and evaluate the Fortran code for
   a) need for structured programming
   b) alternative languages
   c) alternative development environments
   d) appropriate and necessary QA/QC procedures
   e) Components that can better be implemented in RDBMS
   f) Errors in the process algorithm
   g) Errors in program logic
   h) Fortran errors
2. make appropriate recommendations based on Task 1.
3. modify the Snake Storage Report.
4. migrate RDBMS functions from Access to SQL Server after development is completed

6.4.7 Status

Work not yet begun

6.5 Initiative 5: Document Water Rights Accounting

6.5.1 Initiative Goal

Transfer institutional memory from personnel to process.

6.5.2 Initiative Objectives

1. Create program documentation to clarify how the model works

2. Provide the necessary information about the model so the impacts of modifications will be predictable and understood.

3. Link model coefficients to official decisions. (BOR contracts, decrees, etc)

6.5.3 Tasks

1. Consolidate and make available all available publications that document the model. These publications include especially 1) Sutter (1982) and 2) Sandoval (1992).
2. Document the controlling authority for each of the numbers attached to model components (water rights, reservoir storage accounts, etc.)

6.5.3 Status

Task 1: Both documents are in electronic form and available at A19:\Water_Right_Accounting\Documentation. Both documents are copyrighted, so only they are not available on the Water Rights Accounting web page.

Task 2: Not yet begun

6.6 Initiative 6: Develop a Strategy to Keep the Model Current

6.6.1 Introduction

The water rights accounting model needs to evolve to take advantage of increasing functionality of information technology tools. As the increasing IT functionality is incorporated into the model, the model will be able to more easily handle the needs of increased modeling functionality.

Historically, the model has not evolved with information technology tools, which has had a negative impact of model functionality, and now makes adoption of those modern tools more difficult. The relationship between the accounting model and information technology tools as a function of time is illustrated by Figure 5.
Information technology, in the form of hardware, software, and connectivity, evolves rapidly. Water Rights Accounting, as a business process, needs to be reviewed regularly to evaluate how it can take advantage of advances in Information Technology.

6.6.2 Initiative Goal

Maintain the quality, usability, and currency of the accounting model.

6.6.3 Initiative Objective

More closely match the model functionality with IT functionality over time, as illustrated by the blue stair-step line after 2005.

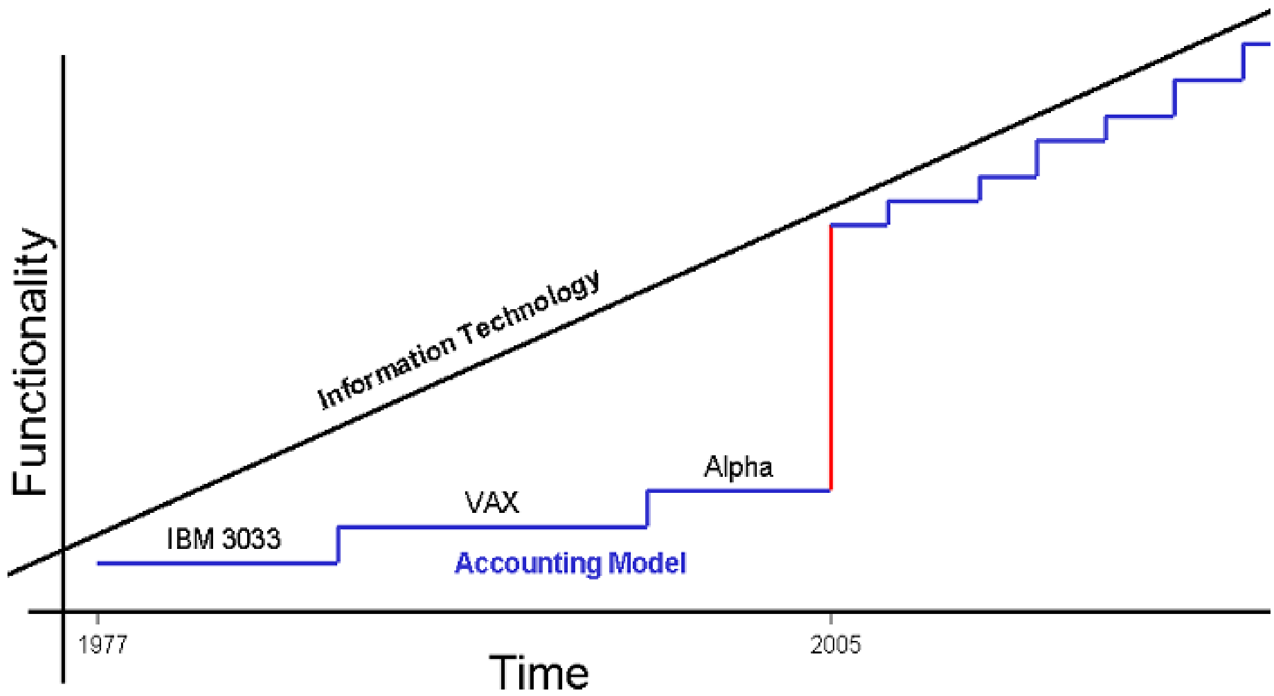


Figure 5. A conceptional representation of a desirable relationship of functionality over time between information technology tools and the water rights accounting model. Prior to 2005, the accounting model was rarely updated to add new IT tools. The vertical, red line represents the relative level of effort needed to modernize the accounting model. The blue stair-step lines after 2005 illustrate the relative frequency and intensity of updating needed.

6.6.4 Tasks

1. Define a strategy for assuring personnel to stay current in IT.

   a) Training

      1) Hydrology specialized topics
      2) Specialized Hydrology software (e.g. modeling packages)
      3) Related software (e.g. GIS, RDBMS)
      3) General software (e.g. operating systems,

   b) Education (what courses at BSU or UI would personnel benefit from)

2. Design implementation of strategy.

6.6.5 Status

Work has not yet begun.

7.0 Glossary

The following definitions have been assembled from various sources.

ArcIMS – ArcIMS is server-based software that enables web publishing of GIS maps, data, and metadata through focused GIS applications by users on the World Wide Web using Web-browser software.

Alpha – The DEC Alpha, also known as the Alpha AXP, is a 64-bit RISC microprocessor originally developed and fabricated by Digital Equipment Corp. Designed as a successor to the VAX line of computers, it supported the VMS operating system.

DEC – Digital Equipment Corporation. DEC was purchased outright by Compaq Corp., and Compaq was acquired by Hewlett Packard, Inc.

GIS – (Geographic Information system). Special-purpose digital databases in which a common spatial coordinate system is the primary means of reference. GIS contain subsystems for: 1) data input; 2) data storage, retrieval, and representation; 3) data management, transformation, and analysis; and 4) data reporting and product generation. It is useful to view GIS as a process rather than a thing. A GIS supports data collection, analysis, and decision making and is far more than a software or hardware product.

RDBMS – (Relational Database Management System). Information storage system in which there is an association between two or more things. Organized according to relationships between data items. Collection of tables that are logically associated to each other by shared common attributes. Entering the table name, attribute name, and the value of the primary key, any data element or set of elements can be retrieved. Consists of table rows and columns.

Hydrography - Map data that describes the positions and characteristics of bodies of water.

IT – Information technology

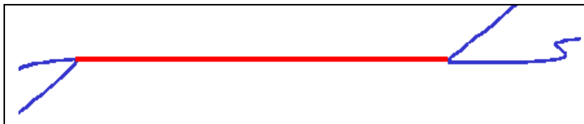
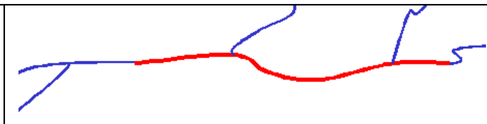
Network - A system of spatially or functionally interconnected geographic features such as a system of streams, rivers, and lakes.

NHD – National Hydrography Dataset

POD – Point of Diversion. For surface water, a POD is generally the place where water is diverted out of a stream for irrigation. In hydrologic modeling, a POD may not be the physical site of the diversion from the river, but rather the site down-stream on a canal where the volume of diverted water is measured.

POU – Place of Use. In the case of irrigation, the field (or place) on which water is used for the purpose of growing a crop.

Reach (or River Reach) – A segment of a river. In a GIS context, a reach is defined as that part of a river between two confluences. For the purposes of Hydrologic Modeling, a reach is any arbitrary segment of a river, regardless of confluences, that has a modeling significance.

	
A GIS reach	Hydrologic modeling reach

SDE – Spatial Database Engine. Spatial Database Engine is server-based software that runs in conjunction with a relational database management system and allows GIS data to be stored and managed with relational database tools.

Topology - A set of defined relationships between links, nodes, and centroids. Topology describes how lines and polygons connect and relate to each other, and forms the basis for advanced GIS functions, such as network tracing and spatial analysis.

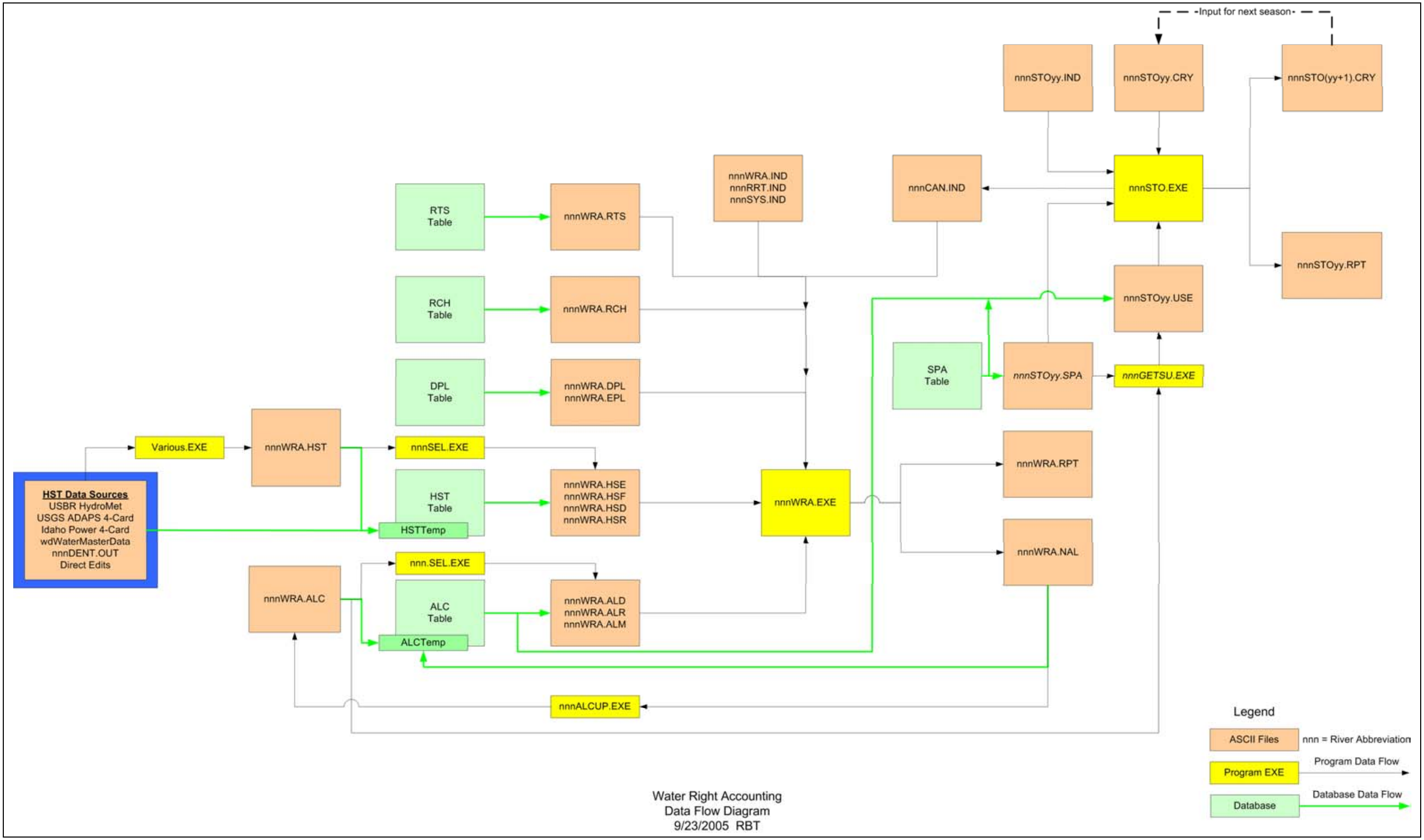
WRA – Water Rights Accounting

8.0 References

Sutter, R.J., R.D. Carlson, and D. Lute; 1982; Data Automation for Water Supply Management; Proceedings of the American Society of Civil Engineers Planning and Management Division specialty Conference; Lincoln, NB.

Sandoval, V.B.; 1992; Water Rights Accounting on the Upper Snake River, Water District 01, Southeastern Idaho; MS Thesis; University of Idaho; Moscow, ID; 416pps.

9.0 Appendix 1 Generalized data flow



10.0 Appendix 2 Project Personnel

Steve Baker	Programming
Ben Britton	ArcIMS programming
Steve Burrell	Accounting / programming
Linda Davis	GIS design, data discipline
Helga King	Accounting
Weimin Li	Programming
Tony Morse	Project management
Tony Olenichak	Accounting
Rick Raymondi	Project management
Liz Robbins	Accounting
Bob Sutter	Original developer
Lyle Swank	Accounting
Bruce Tuttle	Database design and programming
Sean Vincent	Project management